

We claim:

- 1 1. A process for cleaving one or more
2 hydroperoxides selected from the group consisting of s-
3 butylbenzene hydroperoxide, cumene hydroperoxide, and
4 combinations thereof, the process comprising:
5 feeding a cleavage reaction feed to a cleavage
6 reactor to produce a cleavage reaction mixture
7 comprising the one or more hydroperoxides; and
8 subjecting the cleavage reaction mixture to cleavage
9 reaction conditions effective to produce a
10 cleavage reaction product comprising phenol and
11 one or more components selected from the group
12 consisting of methyl ethyl ketone (MEK),
13 acetone, and combinations thereof;
14 wherein the cleavage reaction conditions comprise a
15 cleavage reaction temperature of less than 75 °C
16 which is sufficiently high to cleave a majority
17 of the one or more hydroperoxides but
18 sufficiently low to produce a first quantity of
19 non-recoverable byproducts from components
20 selected from the group consisting of
21 dimethylbenzyl alcohol (DMBA), ethyl methyl
22 benzyl carbinol (EMBA), and combinations
23 thereof, the first quantity of said non-
24 recoverable byproducts being less than a second
25 quantity of said non-recoverable byproducts
26 produced by the same process at a cleavage
27 reaction temperature of 75 °C or higher.
- 1 2. The process of claim 1 wherein:
2 wherein said cleavage reaction feed comprises from
3 about 0.5 wt.% to 2 wt.% water and a ketone
4 stream selected from the group consisting of an
5 acetone stream, a MEK stream, and a mixed
6 acetone/MEK stream; and
7 said cleavage reaction conditions comprise feeding
8 the first cleavage reaction feed to a first
9 cleavage reactor and subjecting the first

10 cleavage reaction feed to first cleavage
11 reaction conditions effective to produce a
12 first cleavage reaction mixture comprising a
13 first cleavage reaction product, and feeding
14 the first cleavage reaction product to a second
15 cleavage reactor to produce a second cleavage
16 reaction mixture and subjecting the second
17 cleavage reaction mixture to second cleavage
18 reaction conditions effective to produce a
19 second cleavage reaction product.

1 3. The process of claim 2 wherein the second
2 cleavage reaction conditions comprise a second cleavage
3 reaction temperature effective convert DMBA to α -methyl
4 styrene and to convert EMBA to one or more compound
5 selected from the group consisting of α -ethyl styrene
6 (AES), 2-phenyl-2-butene (2P2B), and combinations
7 thereof.

1 4. The process of claim 1 wherein said first
2 cleavage reaction conditions comprise feeding to the
3 first cleavage reaction mixture an acid catalyst
4 effective to catalyze the cleavage of hydroperoxides
5 selected from the group consisting of s-butylbenzene
6 hydroperoxide, cumene hydroperoxide, and combinations
7 thereof.

1 5. The process of claim 2 wherein said first
2 cleavage reaction conditions comprise feeding to the
3 first cleavage reaction mixture an acid catalyst
4 effective to catalyze the cleavage of hydroperoxides
5 selected from the group consisting of s-butylbenzene
6 hydroperoxide, cumene hydroperoxide, and combinations
7 thereof.

1 6. The process of claim 3 wherein said first
2 cleavage reaction conditions comprise feeding to the
3 first cleavage reaction mixture an acid catalyst
4 effective to catalyze the cleavage of hydroperoxides
5 selected from the group consisting of s-butylbenzene
6 hydroperoxide, cumene hydroperoxide, and combinations
7 thereof.

1 7. The process of claim 4 wherein the acid
2 catalyst is selected from the group consisting of
3 sulfuric acid, sulfuric acid anhydride, perchloric acid,
4 and phosphoric acid.

1 8. The process of claim 5 wherein the acid
2 catalyst is selected from the group consisting of
3 sulfuric acid, sulfuric acid anhydride, perchloric acid,
4 and phosphoric acid.

1 9. The process of claim 6 wherein the acid
2 catalyst is selected from the group consisting of
3 sulfuric acid, sulfuric acid anhydride, perchloric acid,
4 and phosphoric acid.

1 10. The process of claim 4 wherein the acid
2 catalyst comprises sulfuric acid.

1 11. The process of claim 5 wherein the acid
2 catalyst comprises sulfuric acid.

1 12. The process of claim 6 wherein the acid
2 catalyst comprises sulfuric acid.

1 13. The process of claim 6 wherein the first
2 cleavage reactor and the second cleavage reactor are
3 selected from the group consisting of plug-flow reactors,
4 plug-flow reactors with recycle, and continuous stirred
5 tank reactors.

1 14. The process of claim 12 wherein the first
2 cleavage reactor and the second cleavage reactor are
3 selected from the group consisting of plug-flow reactors,
4 plug-flow reactors with recycle, and continuous stirred
5 tank reactors.

1 15. The process of claim 6 wherein the first
2 cleavage reactor is a stirred tank reactor comprising
3 internal or external heat exchangers effective to
4 maintain the first cleavage reaction mixture at a first
5 cleavage reaction temperature.

1 16. The process of claim 12 wherein the first
2 cleavage reactor is a stirred tank reactor comprising
3 internal or external heat exchangers effective to
4 maintain the first cleavage reaction mixture at a first
5 cleavage reaction temperature.

1 17. The process of claim 6 wherein the first
2 cleavage reactor is a pipeline loop reactor comprising
3 one or more heat exchangers effective to maintain a first
4 cleavage reaction mixture at a first cleavage reaction
5 temperature.

1 18. The process of claim 12 wherein the first
2 cleavage reactor is a pipeline loop reactor comprising
3 one or more heat exchangers effective to maintain a first
4 cleavage reaction mixture at a first cleavage reaction
5 temperature.

1 19. The process of claim 1 wherein the first
2 cleavage reaction conditions comprise
3 a first cleavage reaction temperature of from about
4 45°C to about 70°C;
5 a first cleavage reaction pressure sufficiently high
6 to maintain the first cleavage reaction mixture
7 in the liquid phase; and,
8 a first cleavage reaction residence time effective
9 to cleave about 95% or more of s-butylbenzene
10 hydroperoxide in the first cleavage reaction
11 mixture to phenol and MEK and to cleave about
12 95% or more of cumene hydroperoxide in the
13 first cleavage reaction mixture to phenol and
14 acetone.

1 20. The process of claim 2 wherein the first
2 cleavage reaction conditions comprise
3 a first cleavage reaction temperature of from about
4 45°C to about 70°C;
5 a first cleavage reaction pressure sufficiently high
6 to maintain the first cleavage reaction mixture
7 in the liquid phase; and,
8 a first cleavage reaction residence time effective
9 to cleave about 95% or more of s-butylbenzene
10 hydroperoxide in the first cleavage reaction
11 mixture to phenol and MEK and to cleave about
12 95% or more of cumene hydroperoxide in the
13 first cleavage reaction mixture to phenol and
14 acetone.

1 21. The process of claim 3 wherein the first
2 cleavage reaction conditions comprise
3 a first cleavage reaction temperature of from about
4 45°C to about 70°C;
5 a first cleavage reaction pressure sufficiently high
6 to maintain the first cleavage reaction mixture
7 in the liquid phase; and,
8 a first cleavage reaction residence time effective
9 to cleave about 95% or more of s-butylbenzene
10 hydroperoxide in the first cleavage reaction
11 mixture to phenol and MEK and to cleave about
12 95% or more of cumene hydroperoxide in the
13 first cleavage reaction mixture to phenol and
14 acetone.

1 22. The process of claim 4 wherein the first
2 cleavage reaction conditions comprise
3 a first cleavage reaction temperature of from about
4 45°C to about 70°C;
5 a first cleavage reaction pressure sufficiently high
6 to maintain the first cleavage reaction mixture
7 in the liquid phase; and,
8 a first cleavage reaction residence time effective
9 to cleave about 95% or more of s-butylbenzene
10 hydroperoxide in the first cleavage reaction
11 mixture to phenol and MEK and to cleave about
12 95% or more of cumene hydroperoxide in the
13 first cleavage reaction mixture to phenol and
14 acetone.

1 23. The process of claim 6 wherein the first
2 cleavage reaction conditions comprise
3 a first cleavage reaction temperature of from about
4 45°C to about 70°C;
5 a first cleavage reaction pressure sufficiently high
6 to maintain the first cleavage reaction mixture
7 in the liquid phase; and,
8 a first cleavage reaction residence time effective
9 to cleave about 95% or more of s-butylbenzene
10 hydroperoxide in the first cleavage reaction

11 mixture to phenol and MEK and to cleave about
12 95% or more of cumene hydroperoxide in the
13 first cleavage reaction mixture to phenol and
14 acetone.

1 24. The process of claim 12 wherein the first
2 cleavage reaction conditions comprise
3 a first cleavage reaction temperature of from about
4 45°C to about 70°C;
5 a first cleavage reaction pressure sufficiently high
6 to maintain the first cleavage reaction mixture
7 in the liquid phase; and,
8 a first cleavage reaction residence time effective
9 to cleave about 95% or more of s-butylbenzene
10 hydroperoxide in the first cleavage reaction
11 mixture to phenol and MEK and to cleave about
12 95% or more of cumene hydroperoxide in the
13 first cleavage reaction mixture to phenol and
14 acetone.

1 25. The process of claim 23 wherein the first
2 cleavage reaction temperature is from about 45°C to about
3 60°C.

1 26. The process of claim 24 wherein the first
2 cleavage reaction temperature is from about 45°C to about
3 60°C.

1 27. The process of claim 23 wherein the first
2 cleavage reaction temperature is from about 45°C to about
3 55°C.

1 28. The process of claim 24 wherein the first
2 cleavage reaction temperature is from about 45°C to about
3 55°C.

1 29. The process of claim 27 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction pressure of about 0.5 atmosphere or more.

1 30. The process of claim 28 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction pressure of about 0.5 atmosphere or more.

1 31. The process of claim 1 wherein the first
2 cleavage reaction conditions comprise recirculating a
3 recycle flow of the first cleavage reaction mixture
4 through the first cleavage reactor.

1 32. The process of claim 2 wherein the first
2 cleavage reaction conditions comprise recirculating a
3 recycle flow of the first cleavage reaction mixture
4 through the first cleavage reactor.

1 33. The process of claim 3 wherein the first
2 cleavage reaction conditions comprise recirculating a
3 recycle flow of the first cleavage reaction mixture
4 through the first cleavage reactor.

1 34. The process of claim 4 wherein the first
2 cleavage reaction conditions comprise recirculating a
3 recycle flow of the first cleavage reaction mixture
4 through the first cleavage reactor.

1 35. The process of claim 6 wherein the first
2 cleavage reaction conditions comprise recirculating a
3 recycle flow of the first cleavage reaction mixture
4 through the first cleavage reactor.

1 36. The process of claim 12 wherein the first
2 cleavage reaction conditions comprise recirculating a
3 recycle flow of the first cleavage reaction mixture
4 through the first cleavage reactor.

1 37. The process of claim 24 wherein the first
2 cleavage reaction conditions comprise recirculating a
3 recycle flow of the first cleavage reaction mixture
4 through the first cleavage reactor.

1 38. The process of claim 31 further comprising
2 withdrawing the first cleavage reaction product from the
3 first cleavage reactor at a first cleavage reaction
4 product withdrawal point upstream of the first cleavage
5 reactor feed.

1 39. The process of claim 37 further comprising
2 withdrawing the first cleavage reaction product from the
3 first cleavage reactor at a first cleavage reaction
4 product withdrawal point upstream of the first cleavage
5 reactor feed.

1 40. The process of claim 31 wherein the recycle
2 flow is greater than the first cleavage reactor feed
3 flow.

1 41. The process of claim 33 wherein the recycle
2 flow is greater than the first cleavage reactor feed
3 flow.

1 42. The process of claim 35 wherein the recycle
2 flow is greater than the first cleavage reactor feed
3 flow.

1 43. The process of claim 37 wherein the recycle
2 flow is greater than the first cleavage reactor feed
3 flow.

1 44. The process of claim 39 wherein the recycle
2 flow is greater than the first cleavage reactor feed
3 flow.

1 45. The process of claim 31 wherein a ratio of the
2 recycle flow to the first cleavage reactor feed flow is
3 from about 10:1 to about 100:1 on a weight basis.

1 46. The process of claim 35 wherein a ratio of the
2 recycle flow to the first cleavage reactor feed flow is
3 from about 10:1 to about 100:1 on a weight basis.

1 47. The process of claim 31 wherein a ratio of the
2 recycle flow to the first cleavage reactor feed flow is
3 from about 20:1 to 40:1 on a weight basis.

1 48. The process of claim 35 wherein a ratio of the
2 recycle flow to the first cleavage reactor feed flow is
3 from about 20:1 to 40:1 on a weight basis.

1 49. The process of claim 43 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction residence time effective to cleave from about
4 95% to about 98% of s-butylbenzene hydroperoxide in the
5 first cleavage reaction mixture to phenol and MEK.

1 50. The process of claim 41 wherein the first
2 cleavage reaction residence time is from about 1 minute
3 to about 10 minutes.

1 51. The process of claim 43 wherein the first
2 cleavage reaction residence time is from about 1 minute
3 to about 10 minutes.

1 52. The process of claim 1 wherein the second
2 cleavage reactor comprises a once through plug flow
3 reactor.

1 53. The process of claim 35 further comprising
2 adding the acid catalyst to a first cleavage reaction
3 mixture side stream at one or more acid addition points.

1 54. The process of claim 43 further comprising
2 adding the acid catalyst to a first cleavage reaction
3 mixture side stream at one or more acid addition points.

1 55. The process of claim 3 wherein the second
2 cleavage reaction conditions comprise a second cleavage
3 reaction temperature and a second cleavage reaction
4 residence time effective to cleave 95 wt.% or more of the
5 hydroperoxides remaining in the second cleavage reaction
6 mixture.

1 56. The process of claim 44 wherein the second
2 cleavage reaction conditions comprise a second cleavage
3 reaction temperature and a second cleavage reaction
4 residence time effective to cleave 95 wt.% or more of the
5 hydroperoxides remaining in the second cleavage reaction
6 mixture.

1 57. The process of claim 38 further comprising
2 withdrawing the first cleavage reaction mixture side
3 stream between the first cleavage reaction product
4 withdrawal point and the first cleavage reactor feed
5 point.

1 58. The process of claim 39 further comprising
2 withdrawing the first cleavage reaction mixture side
3 stream between the first cleavage reaction product
4 withdrawal point and the first cleavage reactor feed
5 point.

1 59. The process of claim 56 wherein the second
2 cleavage reaction conditions are effective to convert 70
3 wt.% or more of DMBA in the first cleavage reaction
4 product to AMS.

1 60. The process of claim 59 wherein the second
2 cleavage reaction conditions are effective to convert 70
3 wt.% or more of EMBA in the first cleavage reaction
4 product to AES, 2P2B, and combinations thereof.

1 61. The process of claim 56 wherein the second
2 cleavage reaction conditions are effective to convert 75
3 wt.% or more of DMBA in the first cleavage reaction
4 product to AMS.

1 62. The process of claim 59 wherein the second
2 cleavage reaction conditions are effective to convert 75
3 wt.% or more of EMBA in the first cleavage reaction
4 product to AES, 2P2B, and combinations thereof.

1 63. The process of claim 56 wherein the second
2 cleavage reaction conditions are effective to convert 85
3 wt.% or more of DMBA in the first cleavage reaction
4 product to AMS.

1 64. The process of claim 59 wherein the second
2 cleavage reaction conditions are effective to convert 85
3 wt.% or more of EMBA in the first cleavage reaction
4 product to AES, 2P2B, and combinations thereof.

1 65. A process for cleaving one or more
2 hydroperoxides selected from the group consisting of s-
3 butylbenzene hydroperoxide, cumene hydroperoxide, and
4 combinations thereof, the process comprising:

5 feeding to a first cleavage reactor at a first
6 cleavage reaction feed flow a cleavage reaction
7 feed comprising from about 0.5 wt.% to 2 wt.%
8 water, a ketone stream selected from the group
9 consisting of an acetone stream, a MEK stream,
10 and a mixed acetone/MEK stream, and an acid
11 catalyst effective to catalyze the cleavage of
12 hydroperoxides selected from the group
13 consisting of s-butylbenzene hydroperoxide,
14 cumene hydroperoxide, and combinations thereof,
15 producing a first cleavage reaction mixture
16 comprising one or more hydroperoxides selected
17 from the group consisting of said s-
18 butylbenzene, said cumene hydroperoxide, and
19 combinations thereof;

20 exposing said first cleavage reaction mixture to
21 first cleavage reaction conditions effective to
22 cleave s-butylbenzene hydroperoxide to phenol

23 and MEK and to cleave cumene hydroperoxide to
24 phenol and acetone,
25 wherein said first cleavage reaction conditions
26 comprise:
27 a first cleavage reaction temperature of less
28 than 75 °C which is sufficiently high to
29 cleave a majority of the one or more
30 hydroperoxides but sufficiently low to
31 produce a first quantity of non-
32 recoverable byproducts from components
33 selected from the group consisting of
34 dimethylbenzyl alcohol (DMBA), ethyl
35 methyl benzyl carbinol (EMBA), and
36 combinations thereof, the first quantity
37 of said non-recoverable byproducts being
38 less than a second quantity of said non-
39 recoverable byproducts produced by the
40 same process at a cleavage reaction
41 temperature of 75 °C or higher;
42 a first cleavage reaction pressure sufficiently
43 high to maintain the first cleavage
44 reaction mixture in the liquid phase;
45 recirculating a recycle flow of the first
46 cleavage reaction mixture through the
47 first cleavage reactor, said recycle flow
48 being greater than the first cleavage
49 reactor feed flow; and
50 feeding the first cleavage reaction product to a
51 second cleavage reactor to produce a second
52 cleavage reaction mixture;
53 subjecting the second cleavage reaction mixture to
54 second cleavage reaction conditions comprising
55 a second cleavage reaction temperature
56 effective to cleave a majority of the one or
57 more hydroperoxides remaining in the second
58 cleavage reaction mixture, to convert a
59 majority of DMBA in the second cleavage
60 reaction mixture to α -methyl styrene, and to

61 convert a majority of EMBA in the second
62 cleavage reaction mixture to one or more
63 compound selected from the group consisting of
64 α -ethyl styrene (AES), 2-phenyl-2-butene
65 (2P2B), and combinations thereof, producing a
66 second cleavage reaction product; and,
67 subjecting the second cleavage reaction product to
68 final conditions effective to produce a final
69 cleavage reaction product comprising phenol and
70 one or more component selected from the group
71 consisting of methyl ethyl ketone (MEK),
72 acetone, and combinations thereof.

1 66. The process of claim 65 wherein a ratio of the
2 recycle flow to the first cleavage reactor feed flow is
3 from about 10:1 to about 100:1 on a weight basis.

1 67. The process of claim 65 wherein a ratio of the
2 recycle flow to the first cleavage reactor feed flow is
3 from about 20:1 to 40:1 on a weight basis.

1 68. The process of claim 65 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction residence time effective to cleave about 95% or
4 more of s-butylbenzene hydroperoxide in the first
5 cleavage reaction mixture to phenol and MEK.

1 69. The process of claim 67 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction residence time effective to cleave about 95% or
4 more of s-butylbenzene hydroperoxide in the first
5 cleavage reaction mixture to phenol and MEK.

1 70. The process of claim 65 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction residence time effective to cleave from about
4 95% to about 98% of s-butylbenzene hydroperoxide in the
5 first cleavage reaction mixture to phenol and MEK.

1 71. The process of claim 65 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction residence time effective to cleave about 95% or
4 more of cumene hydroperoxide in the first cleavage
5 reaction mixture to phenol and acetone.

1 72. The process of claim 68 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction residence time effective to cleave about 95% or
4 more of cumene hydroperoxide in the first cleavage
5 reaction mixture to phenol and acetone.

1 73. The process of claim 69 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction residence time effective to cleave about 95% or
4 more of cumene hydroperoxide in the first cleavage
5 reaction mixture to phenol and acetone.

1 74. The process of claim 72 wherein the first
2 cleavage reaction residence time is from about 1 minute
3 to about 10 minutes.

1 75. The process of claim 73 wherein the first
2 cleavage reaction residence time is from about 1 minute
3 to about 10 minutes.

1 76. The process of claim 72 wherein the acid
2 catalyst is selected from the group consisting of
3 sulfuric acid, sulfuric acid anhydride, perchloric acid,
4 and phosphoric acid.

1 77. The process of claim 72 wherein the acid
2 catalyst comprises sulfuric acid.

1 78. The process of claim 72 further comprising
2 adding the acid catalyst to a first cleavage reaction
3 mixture side stream at one or more acid addition points.

1 79. The process of claim 76 further comprising
2 adding the acid catalyst to a first cleavage reaction
3 mixture side stream at one or more acid addition points.

1 80. The process of claim 77 further comprising
2 adding the acid catalyst to a first cleavage reaction
3 mixture side stream at one or more acid addition points.

1 81. The process of claim 65 further comprising
2 withdrawing the first cleavage reaction mixture side
3 stream between the first cleavage reaction product
4 withdrawal point and the first cleavage reactor feed
5 point.

1 82. The process of claim 78 further comprising
2 withdrawing the first cleavage reaction product from the
3 first cleavage reactor at a first cleavage reaction

4 product withdrawal point upstream of the first cleavage
5 reactor feed.

1 83. The process of claim 65 wherein the second
2 cleavage reaction conditions are effective to convert 70
3 wt.% or more of DMBA in the first cleavage reaction
4 product to AMS.

1 84. The process of claim 65 wherein the second
2 cleavage reaction conditions are effective to convert 70
3 wt.% or more of EMBA in the first cleavage reaction
4 product to AES, 2P2B, and combinations thereof.

1 85. The process of claim 65 wherein the second
2 cleavage reaction conditions are effective to convert 75
3 wt.% or more of DMBA in the first cleavage reaction
4 product to AMS.

1 86. The process of claim 65 wherein the second
2 cleavage reaction conditions are effective to convert 75
3 wt.% or more of EMBA in the first cleavage reaction
4 product to AES, 2P2B, and combinations thereof.

1 87. The process of claim 65 wherein the second
2 cleavage reaction conditions are effective to convert 85
3 wt.% or more of DMBA in the first cleavage reaction
4 product to AMS.

1 88. The process of claim 65 wherein the second
2 cleavage reaction conditions are effective to convert 85
3 wt.% or more of EMBA in the first cleavage reaction
4 product to AES, 2P2B, and combinations thereof.

1 89. A process for cleaving one or more
2 hydroperoxides selected from the group consisting of s-
3 butylbenzene hydroperoxide, cumene hydroperoxide, and
4 combinations thereof, the process comprising:
5 feeding a cleavage reaction feed comprising from
6 about 0.5 wt.% to 2 wt.% water, a ketone stream
7 selected from the group consisting of an
8 acetone stream, a MEK stream, and a mixed
9 acetone/MEK stream, and an acid catalyst to a
10 first cleavage reactor at a first cleavage
11 reaction feed flow, producing a first cleavage
12 reaction mixture, said acid catalyst being
13 effective to catalyze the cleavage of

hydroperoxides selected from the group
consisting of s-butylbenzene hydroperoxide,
cumene hydroperoxide, and combinations thereof;
exposing said first cleavage reaction mixture to
first cleavage reaction conditions effective to
produce a first cleavage reaction product
comprising the one or more hydroperoxides, said
first cleavage reaction conditions comprising a
first cleavage reaction temperature of less
than 75 °C and a first cleavage reaction
pressure sufficiently high to maintain the
first cleavage reaction mixture in the liquid
phase, said first cleavage reaction conditions
further comprising recirculating a recycle flow
of the first cleavage reaction mixture through
the first cleavage reactor, wherein the ratio
of said recycle flow to said first cleavage
reactor feed flow is from about 10:1 to about
100:1 on a weight basis, said first cleavage
reaction conditions being effective to cleave
about 95% or more of s-butylbenzene
hydroperoxide in the first cleavage reaction
mixture to phenol and MEK, to cleave about 95%
or more of cumene hydroperoxide in the first
cleavage reaction mixture to phenol and
acetone, and to produce a first quantity of
non-recoverable byproducts from components
selected from the group consisting of
dimethylbenzyl alcohol (DMBA), ethyl methyl
benzyl carbinol (EMBA), and combinations
thereof, the first quantity of said non-
recoverable byproducts being less than a second
quantity of said non-recoverable byproducts
produced by the same process at a cleavage
reaction temperature of 75 °C or higher; and
feeding the first cleavage reaction product to a
second cleavage reactor to produce a second
cleavage reaction mixture;

52 subjecting the second cleavage reaction mixture to
53 second cleavage reaction conditions comprising
54 a second cleavage reaction temperature
55 effective to cleave 95 wt.% or more of the
56 hydroperoxides remaining in the second cleavage
57 reaction mixture, to convert 70 wt% or more of
58 DMBA in the second cleavage reaction mixture to
59 α -methyl styrene, and to convert 70 wt.% or
60 more of EMBA in the second cleavage reaction
61 mixture to one or more compound selected from
62 the group consisting of α -ethyl styrene (AES),
63 2-phenyl-2-butene (2P2B), and combinations
64 thereof, producing a second cleavage reaction
65 product; and,

66 subjecting the second cleavage reaction product to
67 final conditions effective to produce a final
68 cleavage reaction product comprising phenol and
69 one or more component selected from the group
70 consisting of methyl ethyl ketone (MEK),
71 acetone, and combinations thereof.

1 90. The process of claim 89 wherein said second
2 cleavage reaction conditions comprise a second cleavage
3 reaction temperature effective to cleave 95 wt.% or more
4 of the hydroperoxides remaining in the second cleavage
5 reaction mixture, to convert 75 wt% or more of DMBA in
6 the second cleavage reaction mixture to α -methyl styrene,
7 and to convert 75 wt.% or more of EMBA in the second
8 cleavage reaction mixture to one or more compound
9 selected from the group consisting of α -ethyl styrene
10 (AES), 2-phenyl-2-butene (2P2B), and combinations
11 thereof.

1 91. The process of claim 89 wherein said second
2 cleavage reaction conditions comprise a second cleavage
3 reaction temperature effective to cleave 95 wt.% or more
4 of the hydroperoxides remaining in the second cleavage
5 reaction mixture, to convert 85 wt% or more of DMBA in
6 the second cleavage reaction mixture to α -methyl styrene,
7 and to convert 85 wt.% or more of EMBA in the second

8 cleavage reaction mixture to one or more compound
9 selected from the group consisting of α -ethyl styrene
10 (AES), 2-phenyl-2-butene (2P2B), and combinations thereof

1 92. The process of claim 89 wherein the first
2 cleavage reactor is a pipeline loop reactor comprising
3 one or more heat exchangers effective to maintain a first
4 cleavage reaction mixture at a first cleavage reaction
5 temperature.

1 93. The process of claim 90 wherein the first
2 cleavage reactor is a pipeline loop reactor comprising
3 one or more heat exchangers effective to maintain a first
4 cleavage reaction mixture at a first cleavage reaction
5 temperature.

1 94. The process of claim 91 wherein the first
2 cleavage reactor is a pipeline loop reactor comprising
3 one or more heat exchangers effective to maintain a first
4 cleavage reaction mixture at a first cleavage reaction
5 temperature.

1 95. The process of claim 89 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 70°C.

1 96. The process of claim 90 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 70°C.

1 97. The process of claim 91 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 70°C.

1 98. The process of claim 92 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 70°C.

1 99. The process of claim 93 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 70°C.

1 100. The process of claim 94 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 70°C.

1 101. The process of claim 89 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 60°C.

1 102. The process of claim 90 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 60°C.

1 103. The process of claim 91 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 60°C.

1 104. The process of claim 92 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 60°C.

1 105. The process of claim 93 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 60°C.

1 106. The process of claim 94 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 60°C.

1 107. The process of claim 91 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 55°C.

1 108. The process of claim 92 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 55°C.

1 109. The process of claim 93 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 55°C.

1 110. The process of claim 94 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction temperature of from about 45°C to about 55°C.

1 111. The process of claim 110 wherein the first
2 cleavage reaction conditions comprise a first cleavage
3 reaction pressure of about 0.5 or less.

1 112. The process of claim 89 further comprising
2 withdrawing the first cleavage reaction product from the
3 first cleavage reactor at a first cleavage reaction

4 product withdrawal point upstream of the first cleavage
5 reactor feed.

1 113. The process of claim 111 further comprising
2 withdrawing the first cleavage reaction product from the
3 first cleavage reactor at a first cleavage reaction
4 product withdrawal point upstream of the first cleavage
5 reactor feed.

1 114. The process of claim 89 wherein a ratio of the
2 recycle flow to the first cleavage reactor feed flow is
3 from about 20:1 to 40:1 on a weight basis.

1 115. The process of claim 111 wherein a ratio of the
2 recycle flow to the first cleavage reactor feed flow is
3 from about 20:1 to 40:1 on a weight basis.

1 116. The process of claim 111 wherein the first
2 cleavage reaction residence time is from about 1 minute
3 to about 10 minutes.

1 117. The process of claim 116 wherein the acid
2 catalyst is selected from the group consisting of
3 sulfuric acid, sulfuric acid anhydride, perchloric acid,
4 and phosphoric acid.

1 118. The process of claim 89 wherein the acid
2 catalyst comprises sulfuric acid.

1 119. The process of claim 116 wherein the acid
2 catalyst comprises sulfuric acid.

1 120. The process of claim 89 further comprising
2 adding the acid catalyst to a first cleavage reaction
3 mixture side stream at one or more acid addition points.

1 121. The process of claim 119 further comprising
2 adding the acid catalyst to a first cleavage reaction
3 mixture side stream at one or more acid addition points.

1 122. The process of claim 98 further comprising
2 withdrawing the first cleavage reaction mixture side
3 stream between the first cleavage reaction product
4 withdrawal point and the first cleavage reactor feed
5 point.

1 123. The process of claim 99 further comprising
2 withdrawing the first cleavage reaction mixture side
3 stream between the first cleavage reaction product

4 withdrawal point and the first cleavage reactor feed
5 point.

1 124. The process of claim 122 wherein the amount of
2 acid catalyst fed to the first cleavage reactor is from
3 about 0.005% to about 0.1% by weight based on the first
4 cleavage reactor feed flow.

1 125. The process of claim 123 wherein the amount of
2 acid catalyst fed to the first cleavage reactor is from
3 about 0.005% to about 0.1% by weight based on the first
4 cleavage reactor feed flow.

1 126. The process of claim 89 wherein the second
2 cleavage reactor comprises a once through plug flow
3 reactor.

1 127. The process of claim 124 wherein the second
2 cleavage reactor comprises a once through plug flow
3 reactor.

1 128. The process of claim 125 wherein the second
2 cleavage reactor comprises a once through plug flow
3 reactor.

1 129. The process of claim 89 wherein the second
2 cleavage reaction conditions comprise a second cleavage
3 reaction residence time of from about 5 seconds to about 1.
4 minute.

1 130. The process of claim 89 wherein the second
2 cleavage reaction temperature is from about 60 °C to about
3 130 °C.

1 131. The process of claim 128 wherein the second
2 cleavage reaction temperature is from about 60 °C to about
3 130 °C.

1 132. The process of claim 129 wherein the second
2 cleavage reaction temperature is from about 60 °C to about
3 130 °C.

1 133. The process of claim 109 wherein the second
2 cleavage reaction temperature is from about 70 °C to about
3 120 °C.

1 134. The process of claim 130 wherein the second
2 cleavage reaction pressure is about 30 psig or more.

1 135. The process of claim 89 further comprising
2 taking multiple exotherm measurements to verify the rate
3 of the cleavage reaction.

1 136. The process of claim 134 further comprising
2 taking multiple exotherm measurements to verify the rate
3 of the cleavage reaction.

1 137. The process of claim 135 further comprising
2 controlling the amount of acid catalyst added to the first
3 cleavage reaction mixture based on the multiple exotherm
4 measurements.

1 138. The process of claim 136 further comprising
2 controlling the amount of acid catalyst added to the first
3 cleavage reaction mixture based on the multiple exotherm
4 measurements.

1 139. The process of claim 137 wherein taking the
2 multiple exotherm measurements comprises
3 taking a first reaction mixture side stream exotherm
4 measurement;

5 taking a first cleavage reactor (FCR) exotherm
6 measurement; and,

7 taking a second cleavage reactor (SCR) exotherm
8 measurement.

1 140. The process of claim 138 wherein taking the
2 multiple exotherm measurements comprises

3 taking a first reaction mixture side stream exotherm
4 measurement;

5 taking a first cleavage reactor (FCR) exotherm
6 measurement; and,

7 taking a second cleavage reactor (SCR) exotherm
8 measurement.